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AN INVESTIGATION OF BASIC NOISE PROPERTIES OF FIELD EMISSION.(U)
1977 J KELLY DAAG29-73-C-0007
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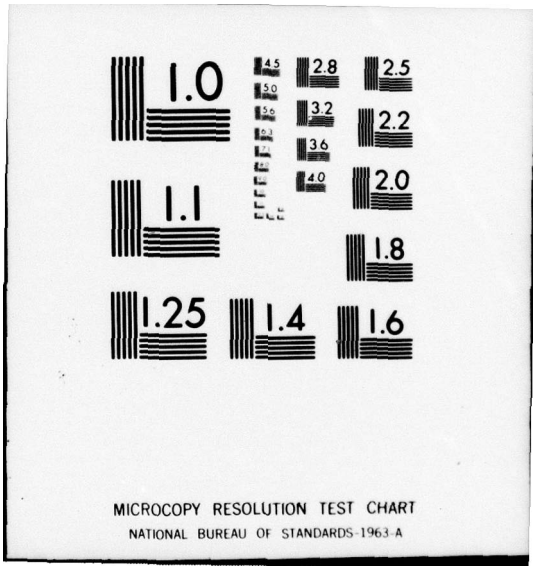
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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: ARO-11101.4-EL	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): AN INVESTIGATION OF BASIC NOISE PROPERTIES OF FIELD EMISSION.	5. TYPE OF REPORT & PERIOD COVERED: Final Report, 1 Jan 73—31 Dec 76
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): John Kelly	8. CONTRACT OR GRANT NUMBER(s): DAAG29-73-C-0007
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Stanford Research Institute, Menlo Park, California 94025	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DAHC04-73-C-0007
11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Research Office, Post Office Box 12211, Research Triangle Park, NC 27709	12. REPORT DATE: 1977
	13. NUMBER OF PAGES: 5
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 5p.	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DDC RECEIVED MAR 16 1977 C

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Thin films
Field Emission
Electronics equipment
Electric current
Variations
Cathodes
Molybdenum

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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1. Lifetimes in excess of 15,000 hours are obtained in conventional ion-pumped vacua ~~(i.e., less than 10^{-8} torr)~~ at currents of 20 ~~μA~~ microamp/cone;

2. Although the low frequency noise is considerably higher than for thermionic emission, it is still well within the requirements of all but very low noise devices; and

3. The basic properties of the arrays of cathodes are such that they can be successfully applied to devices where small area, high current density cathodes are required, with long life and no auxillary power. The work carried out under this contract has demonstrated that the development of the TFFEC represents an important breakthrough in making practical the use of cold field emission cathodes in actual tubes.

FINAL REPORT

ARO Contract Numbers DAHC04-73-C-0007 and DAAG29-73-C-0007

AN INVESTIGATION OF BASIC NOISE PROPERTIES OF FIELD EMISSION

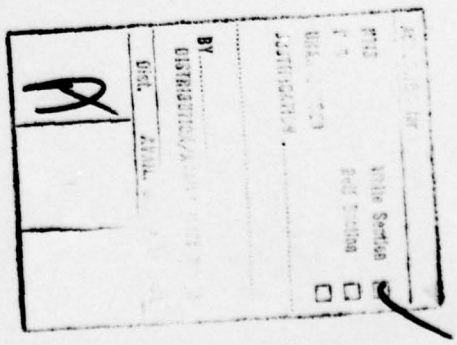
Covering Period 1 January 1972 to 31 December 1976

INTRODUCTION

Despite the unique characteristics of field emission of electrons from sharp points, the utilization of such sources for practical electron devices has proved elusive. The high voltages and extreme vacuum conditions required to run conventional etched points with reasonable life expectancy, and low current fluctuations (flicker noise) have primarily contributed to this elusive utilization.

The development at SRI of a thin film field-emission cathode (TFFEC) based on microfabrication technology has reduced the operating voltage from many thousands of volts to 100-200 volts. This reduction in voltage has been attended by an increase in reliability, the ability to operate in easily attainable high vacua with long life expectancy, and some decrease in flicker noise.

The TFFECs consist of cones of molybdenum approximately 1 μm in height, with tip radii in the range of 400 - 600 Å. The cones are fabricated in a metal oxide silicon structure and are grown on the silicon substrate in holes etched through the metal and silicon dioxide layers. The metal film (molybdenum) acts as a gate or accelerator electrode. The field-emitted electrons are ejected through a hole about 2 μm in diameter in the molybdenum-accelerating electrode and collected by an anode placed a large distance away. Currents between 50 μA and 150 μA can be obtained from each cone.



TFFECs can be formed singly or in arrays. Arrays containing 100 cathodes on 25.4 μm centers and 5000 cathodes on 12.7 μm centers have been built and operated with a remarkable stability and performance.

There are many advantages and potential applications of the TFFEC devices if the anticipated life expectancy and stability can be proven. The advantages include:

- High brightness
- High current density
- No heater power
- Small source size
- Excellent mechanical ruggedness
- Low voltage control.

The potential applications include:

- Electron guns for microwave tubes (TWTs, Klystrons)
- Scanning electron microscopes
- Electron beam semiconductor devices
- Storage tubes
- Camera tubes
- Display tubes.

The purpose of this ARO contract was to investigate the current fluctuations of the TFFEC devices and compare these properties with those of the conventional etched field-emitter points in order to understand the noise limitations of the TFFEC and point to ways to remove them. These studies have benefitted from the availability of cathodes, developed under contract with NASA, for travelling wave tube applications.

RESEARCH FINDINGS FOR FINAL SIX MONTH PERIOD

A. Computation on Electric Fields at the Emitting Surface

Due to the unusual configuration of the electrodes in a TFFEC it is not realistic to use simple approximations to obtain the electric fields over the emitting tip. For this reason a computer program was developed

to solve Laplace's equation for a typical geometry. In this way the value of the factor β, by which the applied voltage has to be multiplied to obtain the electric field, is estimated. In the reporting period the programs were finalized and computations carried out on the effect of the position of the gate electrode on the electric field distribution around the tip. These results confirmed some earlier results, however more work is required to fully evaluate dimensional control of the devices.

B. Burst Noise

The single cone TFFECs also exhibit the phenomenon of burst noise. Burst noise consists of sequences of current pulses of equal amplitude but of variable pulse length and interval between pulses, which are superimposed on the output current of an electronic device. Burst noise has previously been observed in point contact germanium diodes, resistors, forward and reversed biased p-n junctions, tunnel diodes and junction transistors as well as the TFFECs. Despite the wide range of devices in which burst noise has been observed, its character remains remarkably similar in that above a certain output current the amplitude of the burst noise pulse saturates at about 2×10^{-8} A. The noise spectrum taken during a burst exhibits a characteristic in which the noise power is proportional to the inverse power of the frequency squared.

The pulses that form the burst noise are usually so regular in form that a great deal of time was spent trying to understand their physical significance. During the report period we carried out experiments that demonstrated that they are due to the modulation effect of changes of state of single atoms at the emitting surface, however, it has not yet proved possible to identify the adsorbed atoms or quantify the change of state.

GENERAL CONCLUSIONS

Our physical understanding of the mechanism of operation of the TFFE cathodes have been considerably improved over the period of this contract. From the point of view of future practical applcations we have demonstrated

1. Lifetimes in excess of 15,000 hours are obtained in conventional ion-pumped vacua (i.e., less than 10^{-8} torr) at currents of 20 μA/cone.

2. Although the low frequency noise is considerably higher than for thermionic emission, it is still well within the requirements of all but very low noise devices.

3. The basic properties of the arrays of cathodes are such that they can be successfully applied to devices where small area, high current density cathodes are required, with long life and no auxillary power. The work carried out under this contract has demonstrated that the development of the TFFEC represents an important breakthrough in making practical the use of cold field emission cathodes in actual tubes.

PUBLICATIONS

The following papers have been published under ARO sponsorship during the course of this contract:

C.A. Spindt, I. Brodie, L. Humphrey, and E. Westerberg, "Physical Properties of Thin-Film Field Emission Cathodes with Molybdenum Cones", J. Appl. Phys. Vol. 47, No. 12, (1976).

I. Brodie, "Bombardment of Field Emission Cathodes by Positive Ions Formed in the Interelectrode Region", Int'l. J. of Electronics , 38, 541, (1975)

I. Brodie, L. Humphrey, "Burst Noise in Field Emission" Proc. of the 23rd International Symposium, Pennsylvania State University,(Aug. 1976).